

Transceiver Features That Help You Beat Interference

Some of your MF/HF transceiver dollars pay for receiving circuitry intended to help you hear other stations more clearly. Here's how to use that flexibility for better communication.

Adapted from George C. (KC1V) Collins's "Receiver Features That Help You Beat Interference" (February 1983 QST) by David Newkirk, WJ1Z, Assistant Technical Editor

What's most important in the receiver section of a modern MF/HF transceiver? Most operators agree that the ability to produce readable signals in the presence of interference tops the list. Today, even some entry-level transceivers include controls to do this job—but whether we're Extras or Novices, we don't always know how to adjust those controls for best results. This article surveys anti-interference transceiver features and helps you get a handle on how to use them effectively.

IF Filters

In one way or another, each feature we'll examine relates to *selectivity*—a radio's ability to enhance wanted signals and reject interfering ones. Modern transceivers usually obtain selectivity through the use of crystal, ceramic or mechanical filters that operate at one or more of the transceiver's *intermediate frequencies (IFs)*. The IF filters used in a transceiver determine the transceiver's basic selectivity. You can think of IF filters as your first line of defense against interference.

Filter Bandwidth

Transceiver selectivity is specified in terms

of *bandwidth*. A bandwidth of 2400 Hz (2.4 kHz) means that the transceiver responds most strongly to signals spread over a 2400-Hz-wide frequency range. This maximum-response range is often referred to as the transceiver *passband*—the *band* of signal frequencies the transceiver IF *passes*. Normally, the transceiver bandwidth equals that of the IF filter(s) in use at a given time.

Many (but not all) transceivers allow you to select between at least two IF-filter bandwidths. Filters from 2100 to 2700 Hz wide are standard for SSB reception. For CW reception, a filter about 500 Hz wide may be provided, but CW filters are often optional and not included in a basic radio's purchase price. Some transceivers lack provisions for installing a CW-bandwidth IF filter. Instead, CW-bandwidth selectivity is provided through the use of an *audio* or *audio-frequency (AF)* filter. Although audio filters are a less expensive (and somewhat less effective) method of obtaining CW selectivity, they can be satisfactory for casual CW operation. We'll discuss the limitations of audio CW filters later—when we look at audio filtering in general.

Most current transceivers include provisions for other IF bandwidths in addition to the basic SSB and CW bandwidths. For example, you may be able to install a 1700- to 1800-Hz-wide filter for SSB reception and a 250- or 300-Hz-wide filter for CW operation. Transceivers capable of AM reception may allow you to choose between the SSB filter ("AM narrow") and a 4- to 6-kHz-wide filter ("AM wide"). Some transceivers let you select all or most of the IF filters

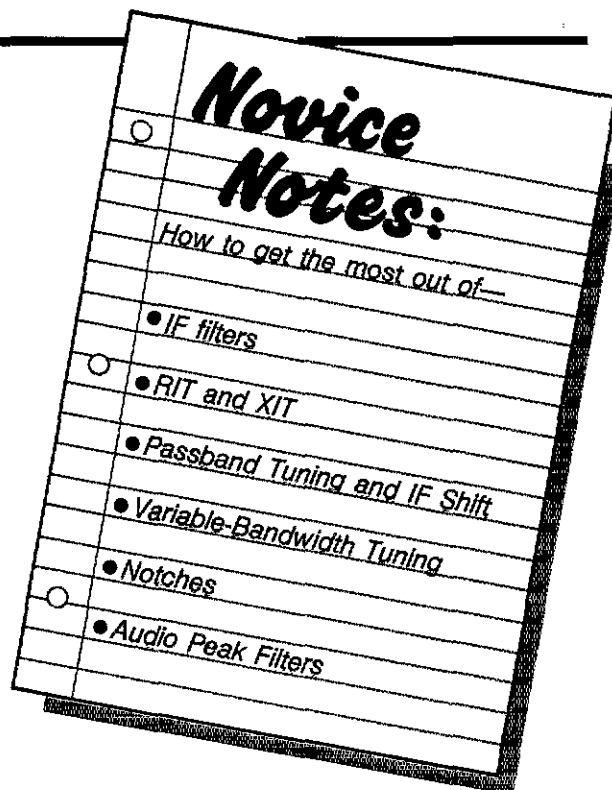
present, regardless of mode. The presence of additional filters can let you better choose the optimum receiving selectivity for a given mode under changing band conditions.

Shape Factor and Ultimate Attenuation

IF filters possess other important characteristics in addition to bandwidth. One of these is *shape factor*—the ratio of the filter bandwidth, measured at a point of high attenuation on the filter response curve, to the bandwidth measured at a low-attenuation point (Fig 1). Shape factor conveys the steepness of the filter *skirts* (passband sides). Steeper skirts improve interference rejection and yield a shape factor closer to 1.

Normally, shape factor evaluates a filter's -6- and -60-dB-response bandwidths. Occasionally, however, shape factor equates bandwidths at other points on a filter's response curve. Keep this in mind when comparing filter specifications, because the points chosen affect the shape factor for a given filter. For example, if the -30-dB bandwidth is used for one filter and the -60-dB point is used for another, the two shape factors could be numerically equal, when, in fact, one filter has much steeper (better) skirt selectivity.

As you follow a filter's selectivity curve away from its center, out of the passband and beyond its skirts, you move into the filter's *stopband*. We prefer—maybe even expect—that the filter passes *no signals at all* in this zone—that it *stops* them cold. But a real filter lets *some* signal energy through in its stopband. *Ultimate attenuation* or *stopband attenuation* describes how much the filter attenuates signals in its stopband.



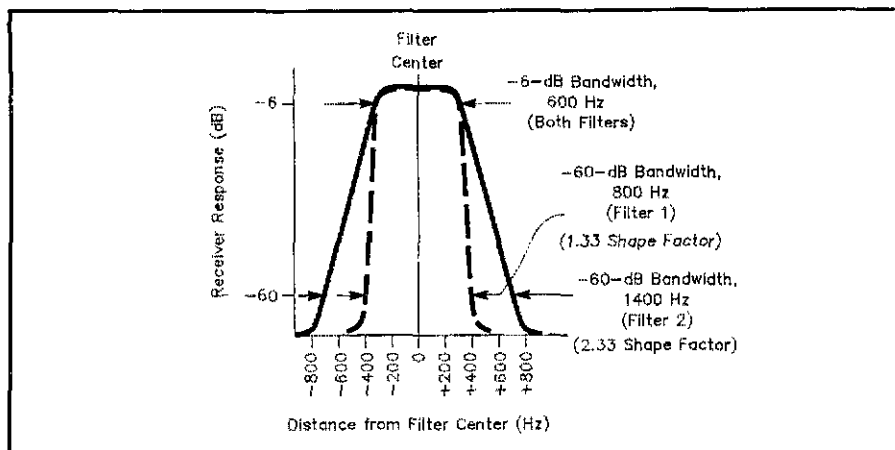


Fig 1—Your transceiver's IF-filter shape factor—the ratio of a filter's selectivity at a high attenuation value (usually 60 dB) to its selectivity at a low attenuation value (often 6 dB)—can tell you a lot about your transceiver's selectivity. The smaller the shape factor—generally, the more rectangular the filter passband—the better the IF filter. In this example, Filter 1 (shape factor 1.33 [800 ÷ 600]) is better than Filter 2 (shape factor 2.33 [1400 ÷ 600]).

Ultimate attenuation depends on filter characteristics and how the filter is used. Poor circuit layout or improper physical filter placement can result in signals leaking around the filter—an effect transceiver users sometimes call *blowby*. Blowby can cause even the best filter to appear to have poor ultimate attenuation.

You can easily spot poor ultimate attenuation by tuning several kilohertz away from a strong signal. If you can still hear the signal (it will be high-pitched), the transceiver

suffers from filter blowby, and/or the filter itself has poor ultimate attenuation.

Many modern transceivers allow you to overcome blowby and improve ultimate attenuation by using similar-bandwidth filters at two transceiver IFs instead of one. Transceiver users know this as *cascade filtering*. For example, a transceiver may come with a 2500-Hz filter at its 9-MHz IF as standard, and allow you the option of adding another 2500-Hz-wide filter at its 455-kHz IF. This results in a net IF bandwidth of somewhat

less than 2500 Hz with much steeper skirts, and greater ultimate attenuation, than is possible with either filter by itself.

RIT, Split and XIT

Most modern transceivers include *receiver incremental tuning* (RIT). RIT does not affect a transceiver's IF bandwidth. Instead, it allows you to adjust your transceiver's receiving frequency without changing your transmitting frequency. During SSB operation, RIT lets you "clarify" incoming signals—make them sound more natural—without changing your transmitting frequency. (This is why some RIT controls are labeled **CLARIFIER**.) During CW operation, RIT lets you correct for operators who call you far enough from your transmitting frequency to make their signals fall outside your transceiver's IF passband.

Why would a CW operator do such a thing? A transceiver set up for CW operation must slightly shift, or offset, its operating frequency when switching between transmit and receive. The amount of this shift is often called *CW offset* or just *offset*. Your transceiver does this so that your CW transmitting frequency will equal that of an incoming signal when you tune the incoming signal so that it's centered in your transceiver's IF passband. (Your transceiver's operating manual may suggest that you do this by tuning the incoming signal for a maximum S-meter reading, or at a particular pitch—often the transceiver's sidetone-oscillator frequency.) Without CW offset, tuning your transceiver to receive another station's CW signal at a comfortable pitch would result in your transmitted signal falling outside the other operator's transceiver passband (Fig 2A). You could call other hams all day this way and they would never know you were there! Offsetting both transceivers' receive frequency solves this problem. Now, tuning your transceiver to the other operator's signal automatically places your transmitted signal in the other operator's transceiver passband (Fig 2B).

But not all hams tune their transceivers for a receiving pitch equal to the CW offset. Snag: If you adjust your transceiver tuning to obtain a desired receiving pitch that differs from the CW offset, your transmit frequency isn't what it should be. The other operator may retune to compensate; you may retune to compensate for him—and the two of you may spend your contact leapfrogging across the band!

RIT enables you to avoid this situation. Once you have established contact with a station, don't use your main tuning control to adjust the received-signal pitch. Instead, make any needed receive frequency adjustments with the RIT control.

All current MF/HF CW/SSB transceivers include circuitry that simulates two or more *variable frequency oscillators* (VFOs). This lets you work *split* (transmit on one frequency and receive on another). With some radios, it's even possible to work split between different bands and/or modes! DX operators often operate split to keep their

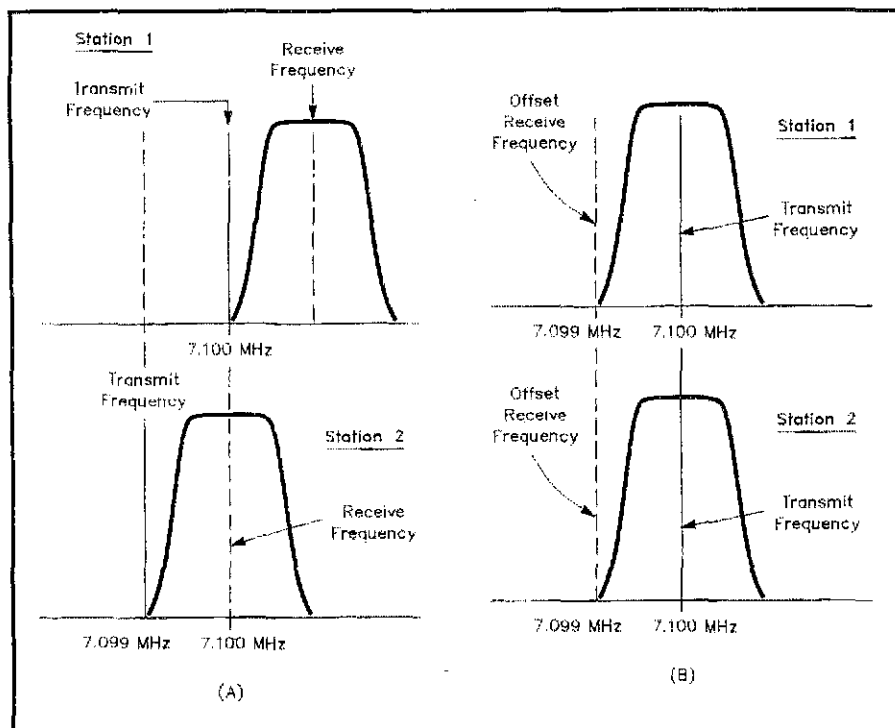


Fig 2—Without CW offset, the transmitting frequencies of two stations in CW contact tend to differ by the receiving pitch (A)—1000 Hz (1 kHz) in this example. CW offset—a built-in frequency jump most MF/HF transceivers make when going from receive to transmit in the CW mode—allows both transceivers to transmit on the same frequency (B). Successful use of CW offset requires that you follow your transceiver manufacturer's instructions for tuning in incoming CW signals.

transmit frequencies clear. (For example, a DX operator who says "Up 5" listens for replies 5 kHz above her transmit frequency. That way, she transmits in the clear, and the pileup ensues 5 kHz higher.)

You can also operate split using one VFO and its RIT circuit. To do this, first determine where the operator you wish to contact is listening. Generally, this is easy because you'll hear other operators calling the DX station on his listening frequency. *With your RIT switched off*, tune to that frequency. This places your transmitter on the correct frequency. Then turn on your RIT and use it to tune in the DX station. Most transceivers have an RIT switch that you can use to turn the RIT on and off without changing the control setting. This is useful because it enables you to easily and quickly check the activity on your transmit frequency. Some transceivers control this function with a momentary **TF SET** (transmit-frequency set) button.

Transmitter incremental tuning (XIT) functions like RIT but shifts your *transmit* rather than receive frequency. Generally, in XIT-equipped transceivers, XIT and RIT shifts are set by the same control, and separate on/off switches are used to select the desired function. In some transceivers, the main tuning knob also adjusts RIT, but separate RIT (and XIT) controls are more common.

Passband Tuning (IF Shift)

This useful receiving feature, introduced in the 1950s by the Collins Radio Company, is called *IF shift* or *passband shift* by some manufacturers. (Confusingly, at least one manufacturer, ICOM, has applied the

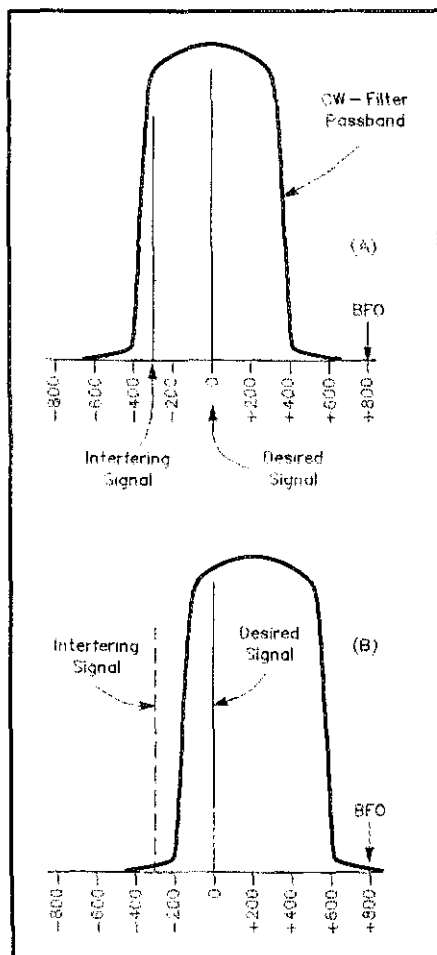


Fig 3—Interference from an undesired signal falling in the transceiver passband (A) can be reduced by IF shift (B).

term *passband tuning* to variable-bandwidth tuning, which we'll discuss shortly.) To avoid confusion, we'll use the term *IF shift* for the control we're discussing now. The principle (and result) is the same, regardless of the name.

IF shift allows you to optimize IF selectivity by changing the effective center frequency of the IF passband *without changing the received-signal pitch*. How can this help? Well, amateur transceivers typically use an IF bandwidth of 500 Hz for CW reception. Although 500 Hz is fairly narrow, two or more CW signals may fall within this bandwidth.

Fig 3A shows this situation. Here, the transceiver has been tuned to center the desired signal in the transceiver's passband. The passband also contains an interfering signal 300 Hz away. The **IF SHIFT** control can change the passband center frequency as shown in Fig 3B. Now the interfering signal falls *outside* the passband, where the filter's stopband attenuation greatly reduces its strength.

Shifting the passband center frequency does not change the transceiver tuning. Thus, IF shift does not change the pitch of received signals. This is so because the frequency difference between the incoming signal (at IF) and the transceiver's BFO (beat-frequency oscillator) determines the pitch of received CW signals. In Fig 3, the BFO frequency is fixed at a point 800 Hz away from IF center, and the transceiver's main tuning knob has been adjusted to place the incoming signal at IF center, 800 Hz away from the BFO. The transceiver's detector and audio-amplifier circuitry outputs only the frequency *difference*

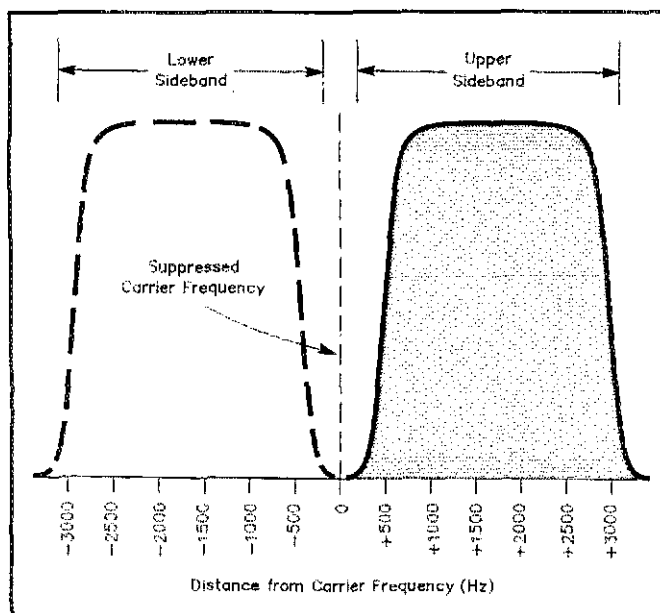


Fig 4—An upper-sideband, suppressed-carrier signal in graphic form. The upper sideband represents the sum of the modulating audio frequencies and the carrier frequency.

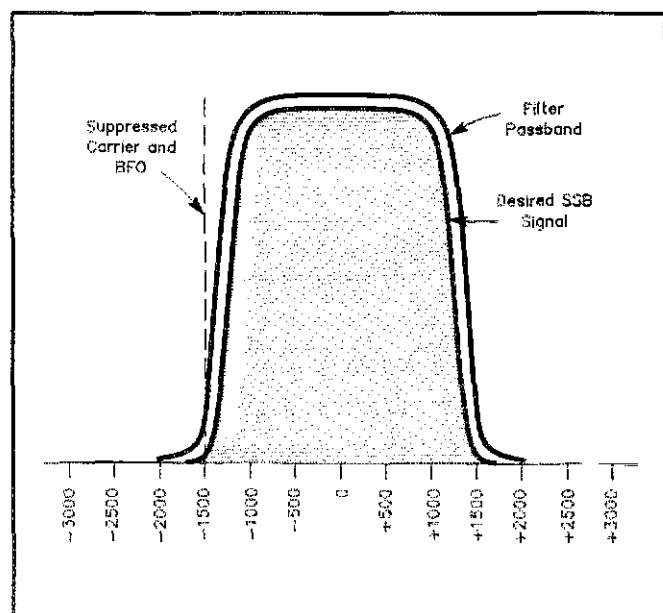


Fig 5—Tuning an SSB signal for correct demodulation superimposes its suppressed carrier on the transceiver BFO.

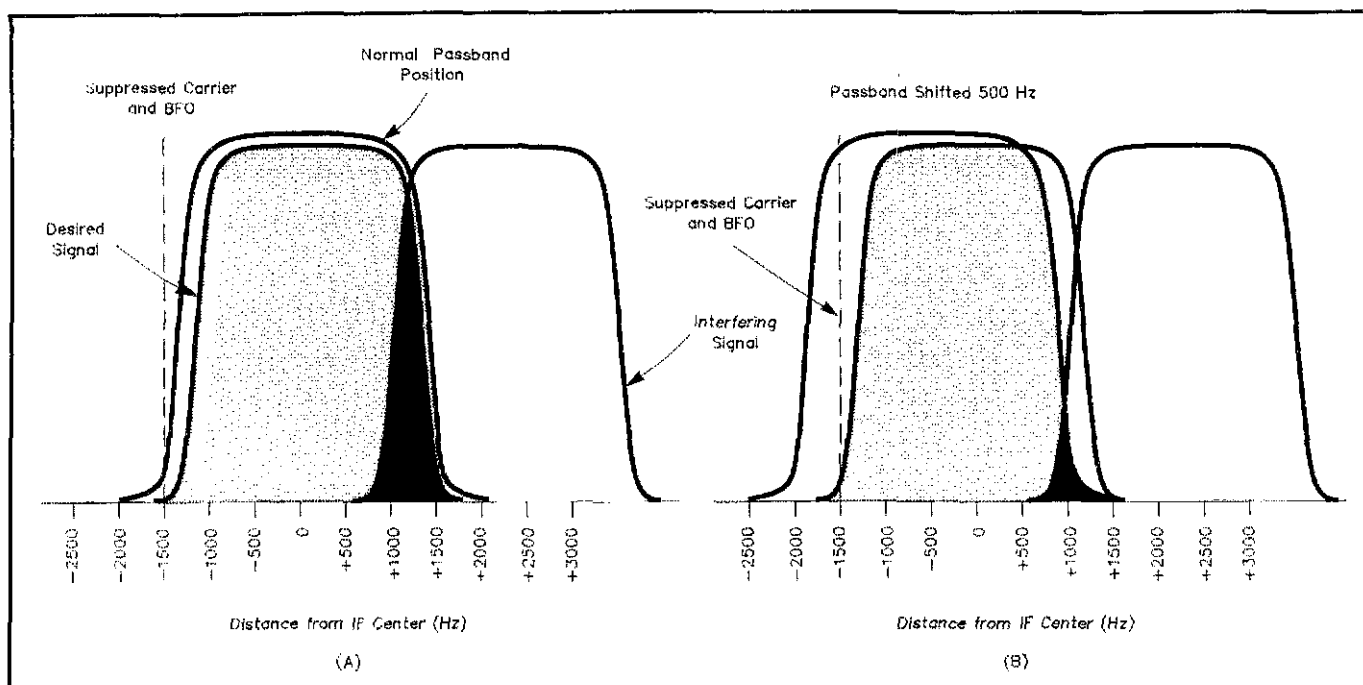


Fig 6—IF shift can reject an interfering SSB signal without disturbing the suppressed-carrier-to-BFO frequency relationship.

between these two signals—800 Hz in this example. You hear this signal in the transceiver speaker or headset.

Why not just tune the transceiver to move the interfering signal entirely out of the passband and listen to the desired signal at a different pitch? You *can* do this, but remember that your transceiver's receive frequency also changes its transmit frequency. What about RIT? You *can* use RIT to tune the receiver independently of the transmitter, but you can only tune so far before the desired signal also falls out of the passband. The solution: Use IF shift to knock down the interfering signal while keeping your desired signal audible (Fig 3B). Of course, you hope that shifting the IF passband doesn't bring in *new* interference that wasn't there before the shift. But careful IF-shift adjustment, and maybe switching in a narrower IF filter as well, can do wonders in reducing interference on CW.

In SSB reception, you can't retune your transceiver to move an interfering signal out of the passband. A look at SSB basics reveals why. Amplitude-modulating a carrier signal produces two sidebands—one above the carrier frequency, the other below. SSB-transceiver transmitting circuitry suppresses the carrier and removes one of the sidebands (generally by filtering—usually with the transceiver's stock SSB-bandwidth IF filter). Fig 4 shows the resulting signal graphically. When you properly tune in an SSB signal (Fig 5), its suppressed-carrier frequency (at the IF) equals that of your transceiver's BFO. (For proper information recovery, the carrier suppressed at the SSB transmitter must be supplied at the SSB receiver; that's the BFO's job in SSB reception.) Mismatch between the BFO and

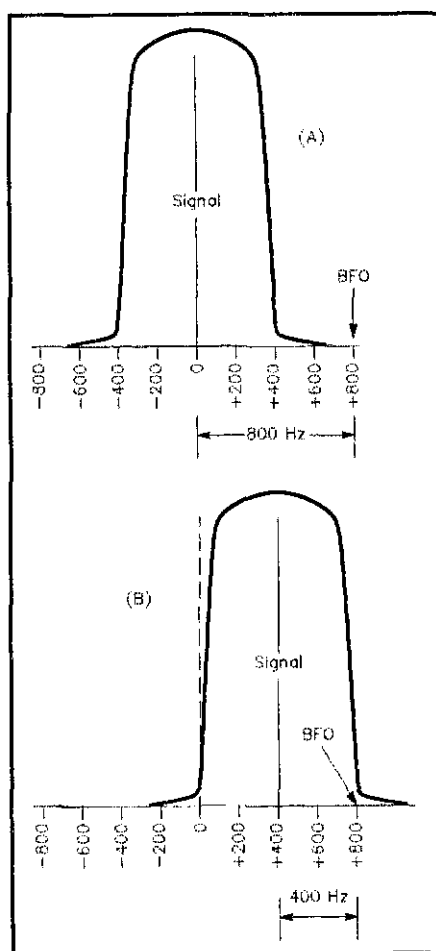


Fig 7—Simultaneous use of IF shift and RIT—or adjusting your transceiver's CW PITCH control—allows you to select a different CW receiving pitch without affecting the transmit frequency.

suppressed-carrier frequencies—that is, tuning in SSB wrong—results in voice signals that sound like anything from Darth Vader to Donald Duck.

So, how can IF shift reject interference during SSB reception? Well, that depends. IF shift can't reduce interference on exactly the same frequency as the signal you want to hear, but such interference is relatively uncommon. More often, the interfering signal's suppressed-carrier frequency is somewhat higher or lower than the desired signal's suppressed carrier, and its sideband overlaps the desired signal. Fig 6A graphs this situation. In this example, a fairly large part of the interfering signal falls within the transceiver passband. Retuning is *out*; that would mismatch the BFO and incoming-signal suppressed carrier.

What *can* we do? Shift the passband! IF shift allows us to place the passband edge, or skirt, *between* the two signals (Fig 6B). This can *greatly* reduce interference from the undesired signal. We don't get something for nothing: Shifting the passband also cuts off part of the desired signal. Fig 6B reveals that we lose some of the desired signal's higher-pitched voice components—it sounds a bit more muffled than usual—in exchange for almost totally eliminating the interference. You can use IF shift to reduce interference from signals on either side of a desired signal. As long as you don't shift the passband too far, you'll still be able to understand the desired signal. So, there are limits on how close the interfering signal can be and still be rejected.

Earlier, we mentioned that IF shift and RIT can be used together. CW operators may find this useful in avoiding the monotony—literally—of listening to the

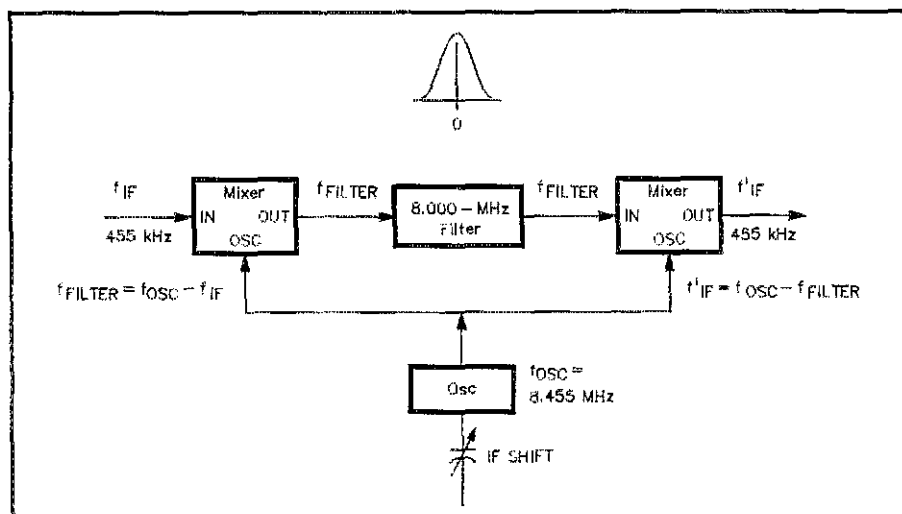


Fig 8—Block diagram of a simple IF-shift circuit. Because the same oscillator converts the signal to the filter frequency and back again, adjusting the IF SHIFT control does not change the receiving pitch. Instead, received signals appear to stand still as the *passband* moves.

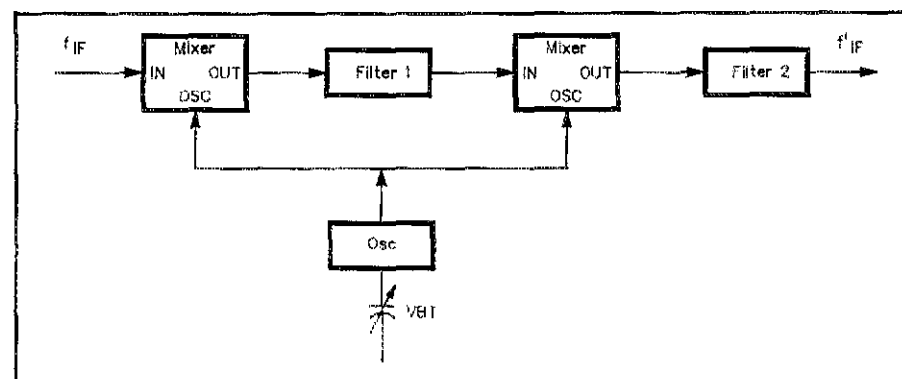


Fig 9—Variable-bandwidth tuning (VBT) can be obtained by placing a second IF filter (Filter 2) at the output of an IF-shift circuit.

same receiving pitch for long stretches. Fig 7A shows a "normal" tuning condition (no IF shift or RIT): The signal appears at IF center (800 Hz from the BFO frequency in our hypothetical transceiver) and the passband is centered over the signal. If you prefer a lower CW-receive pitch, use the RIT control to tune in the signal at that lower pitch. Then use IF shift to center the passband on the incoming signal (Fig 7B).

Some transceivers include a **CW PITCH** control (it may be a front-panel knob, switches or—somewhat less flexibly—a clip-pable PC-board-mounted diode) that shifts the CW offset, IF passband and—in the best implementations—sidetone oscillator all at once by equal amounts. *That's* the way to go, if your transceiver does it!

IF shift may help in data communication if your radio doesn't include a **RTTY** or **FSK** mode selection that optimizes the BFO-to-passband relationship for data MARK and SPACE tones. If your radio's IF-shift circuitry and filter options can't be adjusted to favor the standard high tones (2125 and 2975 Hz for 850-Hz frequency-shift keying

[FSK], 2195 and 2295 Hz for 170-Hz FSK), see if your modem can work at the standard low tones (1275 and 2125 Hz for 850-Hz FSK, 1275 and 1445 Hz for 170-Hz FSK). Use of the low tones was developed to help solve this problem.

How IF Shift Works

IF shift provides the effect of changing the transceiver IF filter's center frequency. Some Amateur Radio receivers of the 1960s and '70s used tuned L-C IF circuits to achieve IF shift. Modern gear usually uses a frequency-conversion process to achieve the same result. A basic such system (Fig 8) uses two mixers fed by one oscillator. The first mixer converts signals at and around IF center (455 kHz in this example) to the crystal-filter frequency (8.000 MHz at center). After passing through the filter, the signal enters the second mixer, which converts it back to the original IF. Changing the oscillator frequency selects the input frequency (f_{IF}) that appears at the filter center frequency. Thus, we can select whatever signals at and near our transceiver IF we want

centered in the filter—without pitch changes, and without changing the transceiver tuning.

IF shift can't cure *all* interference. We've already mentioned one of its limitations: IF shift can't do much against interfering signals too close to the desired signal. If *two* interfering signals appear, one above and one below the desired signal, IF shift may be ineffective in achieving solid copy. In this situation, the only way out is to reduce the passband *width*—perhaps in conjunction with some IF shift. That's where variable-bandwidth tuning comes in.

Variable-Bandwidth Tuning

Multiple crystal filters can allow several discrete selectivity choices, but what if you need an IF bandwidth between two of those choices? *Variable-bandwidth tuning (VBT)* circuits allow you to adjust your transceiver's receive bandwidth to fit band conditions.

One way of implementing VBT (Fig 9) is to place a second filter at the output of the IF-shift circuit shown in Fig 8. The signal must pass through both filters, Filter 1 (the "IF-shift" filter) and Filter 2. Filter 1's passband is "shiftable"; Filter 2's passband is fixed. Aligning Filter 1's passband with Filter 2's produces the system's normal (maximum) bandwidth (Fig 10A). Shifting Filter 1's passband out of this position *reduces* the net IF bandwidth (Fig 10B).

The maximum bandwidth obtainable with VBT is that of the narrower filter in the system, or somewhat less than that of either filter if both filters have the same bandwidth. (If, for example, both filters have 2.7-kHz bandwidths, the maximum net bandwidth will be around 2.4 kHz.) Some VBT circuits allow independent adjustment of the upper- and lower-frequency net-passband skirts; this is sometimes called *slope tuning*.

Because VBT typically allows a *minimum* usable net bandwidth of 100 to 300 Hz, depending on the filters and VBT circuitry involved, VBT can provide reasonable CW IF selectivity in a transceiver equipped only with SSB filters. You may find this satisfactory if you operate CW only occasionally. As you might expect, though, filters tailored for a mode generally provide a VBT range more suitable to that mode: CW filters generally yield narrower minimum net bandwidths than SSB filters. Also, depending on the filters involved, some VBT systems can be adjusted to entirely pinch off IF-signal flow. Misadjusted like this, VBT may make your transceiver seem dead!

Note that in the VBT arrangement outlined in Fig 9, the net-passband center shifts as the net passband narrows. This is academic in SSB reception, but in CW reception it means that the optimum receive pitch varies with VBT. In a transceiver offering simultaneous VBT and IF shift, you may be able to correct for this with IF shift.

Notch Filtering

A *notch filter* selectively attenuates inter-

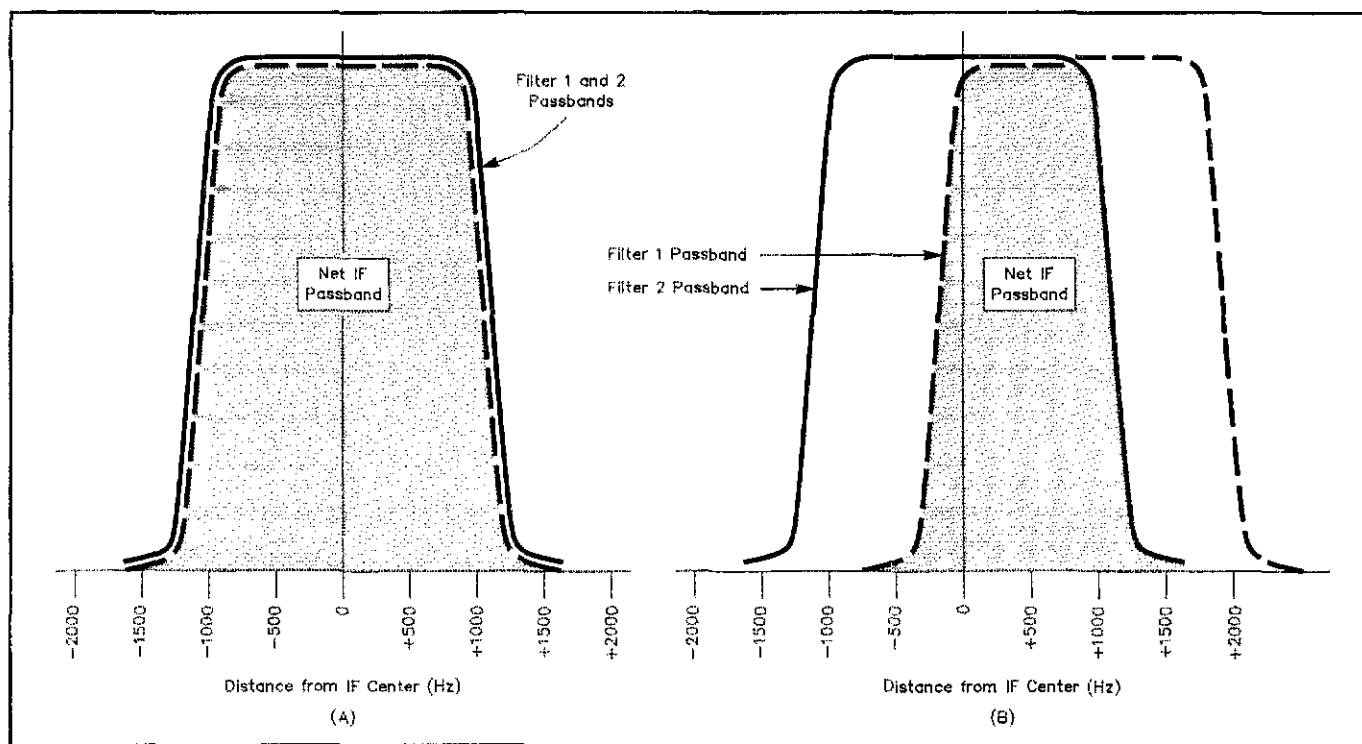


Fig 10—Variable bandwidth tuning is easier to explain with pictures than words! As Filter 1's passband moves higher in frequency, its lower-frequency skirt narrows the net passband like a sliding door.

fering signals that fall *within* the transceiver passband—either at IF (an *IF notch*, Fig 11) or, after detection, at audio (an *AF notch*). You can adjust the notch frequency via a front-panel control. Because the notch must be narrow enough to reduce interference without knocking out a significant chunk of the desired signal, notch filtering is most effective in eliminating narrow-band interference, such as CW signals and unmodulated carriers.

Notch filters typically attenuate interfering signals by 30 to 60 dB. In practical terms, a 30-dB-deep notch can attenuate a 20-dB-over-S9 signal to about S7. A 60-dB notch reduces the same signal to approximately S2. IF notch filters are superior to AF notches because an IF notch can keep the interfering signal from activating your transceiver's automatic-gain-control (AGC) circuitry. (Even if you've knocked it down with an AF notch, a strong incoming signal may grab your transceiver's AGC, desensitizing your transceiver and making weak-signal copy impossible.)

Audio Peak Filters

Some transceivers include *audio peak filters* (APFs)—narrow-bandwidth band-pass filters that allow you to peak audio signals at a particular, usually adjustable, pitch. A good APF is usually a few hundred hertz (or less) wide, and may significantly improve a transceiver's overall CW selectivity whether or not a CW-bandwidth IF filter is already in use. Using an APF *in place of* good CW-bandwidth IF filtering, however, presents a drawback: Because an APF acts on received signals only *after* they've made

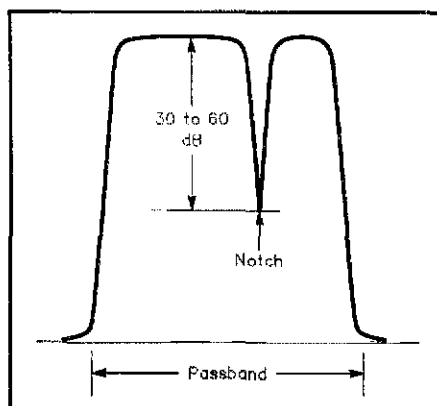


Fig 11—An IF-notch filter knocks out a narrow sliver *within* the transceiver passband. Tuning the notch over an interfering carrier or CW signal reduces the interference to tolerable or inaudible level. AF notch filters do the same thing—at audio.

their way through a transceiver's IF circuitry and detector, strong unwanted signals within the IF passband can activate the transceiver's AGC and desensitize the transceiver even though the APF may render them inaudible. (If your transceiver includes the necessary controls, you can sometimes overcome such desensitization by turning off the AGC and adjusting the transceiver's RF gain yourself.)

Some hams use outboard *fixed-frequency* audio peak filters to improve CW selectivity. If you do this and find that your filter favors a pitch that differs from your trans-

ceiver's CW offset, you may be able to use RIT and IF shift to maximize the transceiver's response at the AF-filter peak.

Which Interference-Rejection Features Should You Shop For?

Many MF/HF transceivers don't include all of the interference-rejection features we've covered. Which features, then, do you *need*? That depends on your operating style and preferences. If you're considering purchasing a new transceiver, think about the features your present equipment *lacks* the next time you run into stiff interference. Would VBT or a notch filter help you out? If so, look for those features when examining a prospective new transceiver. If a friend owns a transceiver that has the features you're considering, ask to try them out. If you're looking to buy your *first* transceiver, understanding what its various receiving controls do (and don't do) can help you make your purchase decision.

Read the Manual!

Owning a transceiver with the right interference-rejection features is only half the battle: You must *use* those features to benefit from them! And you can't use those features well until you know *how* to use them. So, once you've got the gear, *read your operating manual carefully* and scan the bands, amateur and otherwise, for receiving challenges. It won't be long before you can wring the last ounce of readability out of just about any station buried in heavy interference. That way, when interference gets tough during your QSOs, you'll beat it before it beats you. 